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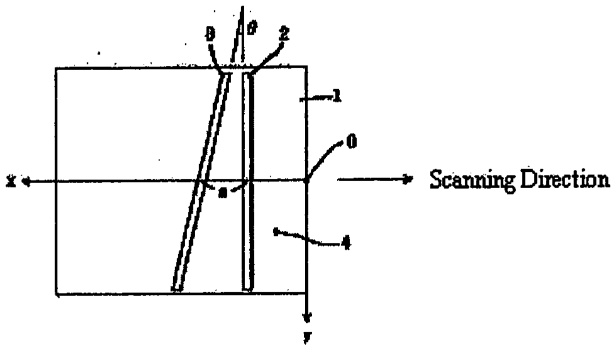
(54) [Title of the Invention] Surface Foreign Matter Inspection Apparatus

(57) [Abstract]
[Object] To detect with high precision the position of foreign matter extending over an entire large inspection surface, without increasing the size of an apparatus.
[Constitution] An irradiation means forms a first band-shaped irradiation region and a second band-shaped irradiation region whose distance from said first band-shaped irradiation region changes monotonously, and a detection means for detecting the position of foreign matter on the basis of when foreign matter was detected in the first band-shaped irradiation region, when foreign matter was detected in the second band-shaped irradiation region, and the relative movement speed of the inspection surface and the irradiation means.


3
2
1
0
Scanning Direction
4

[Claims]

[Claim 1] A surface foreign matter inspection apparatus, comprising:

irradiation means for forming a band-shaped irradiation region on an inspection surface;

scanning means for moving the inspection surface relative to the irradiation means in a direction intersecting the longitudinal direction of the band-shaped irradiation region; and

detection means for detecting the position of foreign matter on the basis of light scattered from the foreign matter in the band-shaped irradiation region,

wherein said surface foreign matter inspection apparatus is characterized in that the irradiation means forms a first band-shaped irradiation region and a second band-shaped irradiation region whose distance from said first band-shaped irradiation region changes monotonously, and

the detection means detects the position of the foreign matter on the basis of when the foreign matter was detected in the first band-shaped irradiation region, when the foreign matter was detected in the second band-shaped irradiation region, and the relative movement speed of the inspection surface and the irradiation means.

[Claim 2] The surface foreign matter inspection apparatus according to Claim 1, characterized in that the first band-shaped irradiation region is formed along a first linear direction perpendicular to the scanning direction, and the second band-shaped irradiation region is formed along a second linear direction that intersects the first linear direction at a specific angle.

[Claim 3] The surface foreign matter inspection apparatus according to Claim 1 or 2, characterized in that the scanning means is a stage means that supports an object having the inspection surface and that is able to move in the scanning direction.

[Claim 4] The surface foreign matter inspection apparatus according to any of Claims 1 to 3, characterized in that the irradiation means comprises:

a first irradiation system for forming the first band-shaped irradiation region on the inspection surface; and

a second irradiation system for forming the second band-shaped irradiation region on the inspection surface, and

the detection means comprises:

first light guide means for receiving and propagating light scattered from the first band-shaped irradiation region;

a first photoelectric conversion element for photoelectrically converting the light scattered from the first band-shaped irradiation region in which the first light guide means is interposed;

second light guide means for receiving and propagating light scattered from the second band-shaped irradiation region; and

a second photoelectric conversion element for photoelectrically converting the light scattered from the second band-shaped irradiation region in which the second light guide means is interposed.

[Claim 5] The surface foreign matter inspection apparatus according to Claim 4, characterized in that the detection means further comprises:

a first lens array for converging light scattered from the first band-shaped irradiation region;

a second lens array for converging light scattered from the second band-shaped irradiation region;

a first field stop provided at a location that is substantially the optical conjugate of the first band-shaped irradiation region; and

a second field stop provided at a location that is substantially the optical conjugate of the second band-shaped irradiation region,

the first light guide means receives light scattered from the first band-shaped irradiation region in which the first lens array and the first field stop are interposed, and

the second light guide means receives light scattered from the second band-shaped irradiation region in which the second lens array and the second field stop are interposed.

[Claim 6] The surface foreign matter inspection apparatus according to any of Claims 1 to 3, characterized in that the irradiation means comprises:

a first irradiation system for forming the first band-shaped irradiation region on the inspection surface; and

a second irradiation system for forming the second band-shaped irradiation region on the inspection surface, and

the detection means comprises:

a first photoelectric conversion element for receiving and photoelectrically converting the light scattered from the first band-shaped irradiation region; and

a second photoelectric conversion element for receiving and photoelectrically converting the light scattered from the second band-shaped irradiation region.

[Detailed Description of the Invention]

[0001]
Technological Field to Which the Invention Belongs

The present invention relates to a surface foreign matter inspection apparatus for detecting foreign matter adhering to an inspection surface, and more particularly relates to an apparatus for detecting the position of foreign matter on a pellicle of a large mask used in an exposure device that forms circuit patterns for flat panel displays and so forth.

[0002]
Prior Art

In the manufacture of the circuit patterns for flat panel displays and the like, a pattern is formed on a mask covered with a thin film that prevents the adhesion of foreign matter (that is, a pellicle), and this pattern is transferred to a photosensitive substrate. If dust or other such large foreign matter should adhere to the pellicle, this foreign matter will be transferred onto the substrate, resulting in defects in the circuit pattern. Therefore, a surface foreign matter inspection apparatus must be used to detect the presence and the position of any foreign matter prior to transfer.

[0003] With a conventional surface foreign matter inspection apparatus of this type, a beam spot is scanned over the inspection surface using a scanning optical system, and light scattered from

any foreign matter (microscopic dust or the like) with respect to the beam spot is detected through a light-receiving optical system. Alternatively, the inspection surface is irradiated with illuminating light, and light scattered from the foreign matter with respect to the illuminating light is detected through a CCD or other such image detecting device. When an image detecting device is employed, the inspected region on the inspection surface must be projected in reduced size via a reducing projection optical system onto the image detecting device in order to obtain a wider inspection field.

[0004]
[Problems Which the Invention is Intended to Solve]

However, the masks used in exposure devices that form circuit patterns for flat panel displays and so forth are steadily increasing in size. Consequently, with a conventional inspection apparatus that scans a beam spot, the scanned area increases along with the size of the mask. As a result, the scanning optical system and the light-receiving optical system require larger fields, which makes it much more difficult to design and manufacture the optical systems. Also, as the required fields become larger, so do the various optical elements used, which limits the layout thereof.

[0005] Furthermore, with a conventional inspection apparatus that makes use of image detecting devices, a larger mask necessitates larger optical elements, or a smaller reduction ratio of the light-receiving optical system. As a result, the inspection apparatus may end up being larger, or the sensitivity at which the foreign matter positions are detected may vary with the positions.

[0006] The present invention was conceived in light of the above problems, and it is an object thereof to provide a surface foreign matter inspection apparatus with which the position of foreign matter can be detected to high precision over an entire large inspection surface, without the apparatus becoming bulkier.

[0007]
[Means Used to Solve the Above-Mentioned Problems]

In order to solve the above problems, the present invention provides a surface foreign matter inspection apparatus, comprising irradiation means for forming a band-shaped irradiation region on an inspection surface, scanning means for moving the inspection surface relative to the irradiation means in a direction intersecting the longitudinal direction of the band-shaped irradiation region, and detection means for detecting the position of the foreign matter on the basis of light scattered from the foreign matter in the band-shaped irradiation region, wherein said surface foreign matter inspection apparatus is characterized in that the irradiation means forms a first band-shaped irradiation region and a second band-shaped irradiation region whose distance from said first band-shaped irradiation region changes monotonously, and the detection means detects the position of the foreign matter on the basis of when the foreign matter was detected in the first band-shaped irradiation region, when the foreign matter was detected in the second band-shaped irradiation region, and the relative movement speed of the inspection surface and the irradiation means.

[0008] In a preferred embodiment of the present invention, the first band-shaped irradiation region is formed along a first linear direction perpendicular to the scanning direction, and the second band-shaped irradiation region is formed along a second linear direction that intersects the first linear direction at a specific angle.

[0009]
[Embodiments of the Invention]

In the present invention, a first band-shaped irradiation region and a second band-shaped irradiation region whose distance from the first band-shaped irradiation region changes monotonously are formed on an inspection surface. The inspection surface is then scanned in a specific direction in the first band-shaped irradiation region and the second band-shaped irradiation region. This allows the position of foreign matter to be detected on the basis of the scanning rate and when the foreign matter was detected in each band-shaped irradiation region.

[0010] In a specific embodiment, the first band-shaped irradiation region is formed perpendicular to the scanning direction, and the second band-shaped irradiation region is formed obliquely with respect to the first band-shaped irradiation region. In this case, a foreign matter position along the scanning direction can be detected on the basis of the scanning rate and when the foreign matter was detected in the first band-shaped irradiation region, and a foreign matter position along the direction perpendicular to the scanning can be detected on the basis of the scanning rate and the differential between the times when the foreign matter was detected in each band-shaped irradiation region.

[0011] Thus, in the present invention, a foreign matter position can be detected merely by detecting whether light is being scattered from foreign matter in each irradiation region. Therefore, even if the inspection surface is made larger, foreign matter positions can be detected with high precision over the entire surface without any fluctuation in detection sensitivity. Also, the optical system used for detecting the scattered light from the foreign matter need only have a simple structure consisting of light guides having incident ends extending in a specific direction, for example. As a result, a larger inspection surface can be accommodated merely by lengthening the incident ends of the light guides in a specific direction, without increasing the overall size of the apparatus

[0012] An example of the present invention will now be described through reference to the appended drawings. Fig. 1 is a simplified oblique view of the structure of the surface foreign matter inspection apparatus pertaining to a first example of the present invention. Fig. 2 is a diagram illustrating the two band-shaped irradiation regions formed on the surface of the pellicle 1 in Fig. 1. In Fig. 1, only the irradiation means and detection means corresponding to the band-shaped irradiation region 2 (out of the two band-shaped irradiation regions 2 and 3) are depicted, while the irradiation means and detection means corresponding to the other band-shaped irradiation region 3 are not depicted.

[0013] In Fig. 1, light emitted from a light source 10 forms the band-shaped irradiation region 2 on the surface of a pellicle 1 covering a mask (not shown) via a suitable irradiating optical system 11. The mask is held on a stage (not shown) that can move in the x direction so that the surface of the pellicle 1 will be parallel to the xy plane. The irradiation region 2 is formed in the y direction, which is perpendicular to the scanning direction. Therefore, the entire surface of the pellicle 1 can be scanned by the irradiation region 2 by moving the stage in the x direction.

[0014] Scattered light from the irradiation region 2 is incident on the end face of a fiber bundle 12, which is a light guide means comprising a bundle of numerous optical fibers. The scattered light guided through the fiber bundle 12 is converged on the light-receiving surface of a photoelectric conversion device 13, such as a photoelectron multiplier or a silicon photodiode. This photoelectric conversion device 13 outputs a scatter signal corresponding to the intensity of the scattered light from the foreign matter. Thus, foreign matter can be detected on the basis of the scatter signal.

[0015] The light source 10 and the irradiating optical system 11 constitute the irradiation means for forming the first band-shaped irradiation region 2 on the surface of the pellicle 1 (the inspection surface). The fiber bundle 12 and the photoelectric conversion device 13 constitute the detection means for receiving scattered light from foreign matter in the first band-shaped irradiation region 2 and detecting foreign matter.

[0016] In this first example, as shown in Fig. 2, the second band-shaped irradiation region 3 is formed in addition to the first band-shaped irradiation region 2 formed along the direction (y direction) perpendicular to the scanning direction (x direction). This second band-shaped irradiation region 3 is formed along a direction that intersects the scanning direction and also intersects the longitudinal direction of the first band-shaped irradiation region 2 at a specific angle θ. As discussed above, the irradiation means and detection means corresponding to the second band-shaped irradiation region 3 are not shown in Fig. 1, but the constitution thereof is basically the same as that of the irradiation means and detection means of the first band-shaped irradiation region 2.

[0017] As above, each output signal produced by the conversion of the scattered light from the first and second band-shaped irradiation regions by the respective photoelectric conversion device is inputted to a signal processing system (not shown). Drive information (such as the scanning rate) from the stage holding the mask (what is being inspected) is also inputted to the signal processing system. The signal processing system performs the specified computations (discussed below) and detects the position of foreign matter.

[0018] Fig. 3 consists of graphs of the scatter signal obtained in the first example. Fig. 3a shows the scatter signal from the first band-shaped irradiation region 2, and Fig. 3b shows the scatter signal from the second band-shaped irradiation region 3. In Fig. 3, the horizontal axis is time, based on the point when detection commences, while the vertical axis is the intensity of the optical signal obtained from each irradiation region. Fig. 3 shows the state when an optical signal has been obtained from the irradiation region 2 at the point when time T has elapsed since the start of detection, and an optical signal has been obtained from the irradiation region 3 at the point when time Δt has further elapsed.

[0019] We will now describe how the position of foreign matter 4 is found on the surface of the pellicle 1 through reference to Figs. 2 and 3. In general, in the x direction, the position of the irradiation region 2 at the start of detection can be used as the point of origin. In most cases, scattered light from the edge faces to the mask or from the border of the pellicle 1 is detected substantially all at once from the irradiation region 2, so this scattered light can be used as a

trigger to commence detection. In Fig. 2, the position at which the irradiation region 2 has reached the border of the pellicle 1 is used as the point of origin 0 in the x direction.
[0020] Meanwhile, in the y direction, a position of known distance in the x direction between the irradiation region 2 and the irradiation region 3 can serve as the origin point. In Fig. 2, the position at which the distance is *a* in the x direction between the irradiation region 2 and the irradiation region 3 is used as the origin point 0 in the y direction.

[0021] Under the above conditions, the coordinates (x, y) of the foreign matter 4 are expressed by the following equations 1 and 2.

$$x = v \cdot T \qquad (1)$$

$$y = (v \cdot \Delta t - a)\cot\theta \qquad (2)$$

(Where v is the scanning rate.)

[0022] Thus, in the first example, the position of the foreign matter in the scanning direction (x direction) can be detected on the basis of the scanning rate v and the time T at which the foreign matter 4 was detected in the first band-shaped irradiation region 2. Also, the position of the foreign matter in the direction perpendicular to scanning (y direction) can be detected on the basis of the scanning rate v and the differential Δt in the times at which the foreign matter 4 was detected in the band-shaped irradiation regions 2 and 3.

[0023] Thus, in the first example, the foreign matter position can be detected merely by detecting whether light is being scattered from foreign matter in each of the irradiation regions 2 and 3. Therefore, even if the pellicle 1 (the inspection surface) is made larger, foreign matter positions can be detected with high precision over the entire surface without any fluctuation in detection sensitivity. Also, a larger inspection surface can be accommodated merely by lengthening the incident end of the fiber bundle 12 in a specific direction, without increasing the overall size of the apparatus.

[0024] Fig. 4 is a simplified oblique view of the structure of the surface foreign matter inspection apparatus pertaining to a second example of the present invention. Again in Fig. 4, only the irradiation means and detection means of one of the two band-shaped irradiation regions are depicted, while the irradiation means and detection means corresponding to the other band-shaped irradiation region are not depicted. The constitution of the second example is substantially the same as that of the first example, and in the second example the basic difference from the first example is that a lens array 14 and a field stop 15 are disposed along the optical path between the irradiation region 2 and the fiber bundle 12. Therefore, in Fig. 4, those elements having the same function as the elements in Fig. 1 are numbered the same as in Fig. 1. This second example will now be described, focusing on how it differs from the first example.

[0025] As shown in Fig. 4, in the second example, scattered light from the irradiation region 2 is converged through the lens array 14, after which it is incident on the field stop 15 disposed as an optical conjugate of the irradiation region 2. Specifically, only the scattered light from the irradiation region 2 which has been converged through the lens array 14 reaches the incident end of the fiber bundle 12 through the field stop 15. This design makes it unlikely that light other than scattered light from the irradiation region 2 will reach the incident end of the fiber bundle 12, which avoids the generation of stray light and affords detection of higher precision.

[0026] Further, the first example was for a case in which the irradiation region 2 was perpendicular to the scanning direction, but the longitudinal direction of the irradiation region 2 does not necessarily have to be perpendicular to the scanning direction. The essential point in the present invention is that two irradiation regions be formed intersecting the scanning direction, and that the distance between the two irradiation regions change monotonously. Also, in the examples given above, a fiber bundle is used as the optical element for converting the field of the band-shaped irradiation regions on the light-receiving surface of the photoelectric conversion device, but an integrated light propagation rod or other such optical element may be used instead of a fiber bundle.

[0027] Furthermore, the present invention may be constituted such that, rather than using a fiber bundle or other such light guide means, as shown in Fig. 5, for example, a band-shaped (rectangular) CCD or other such photoelectric conversion device 130 is disposed at a position where scattered light from each band-shaped irradiation region 2 [*sic*] can be detected, the scattered light from the first band-shaped irradiation region is photoelectrically detected by a first photoelectric conversion device, and the scattered light from the second band-shaped irradiation region is photoelectrically detected by a second photoelectric conversion device.

[0028] Furthermore, in each of the above examples, the scattered light from each of the two irradiation regions was received by a separate detection means, but particularly when a light-receiving system such as that in the second example is employed, the light-receiving region is limited because of the joint action of the lens array 14 and the field stop 15, so the two irradiation regions can be entirely irradiated through a single irradiating optical system. Also, two irradiation regions were formed in the above examples, but three or more irradiation regions may also be formed in order to enhance the photosensitivity of position detection and so forth.

[0029]

[Effect of the Invention]

As described above, with the present invention, two band-shaped irradiation regions are formed, and a foreign matter position is detected on the basis of the scanning rate and when the foreign matter was detected in each band-shaped irradiation region. Specifically, a foreign matter position can be detected merely by detecting whether light is scattered from foreign matter in each irradiation region. Therefore, even if the inspection surface is made larger, foreign matter positions can be detected with high precision over the entire surface without any fluctuation in detection sensitivity. Also, a larger inspection surface can be accommodated merely by lengthening the incident end of the fiber bundle in a specific direction, without increasing the overall size of the apparatus.

[Brief Description of the Drawings]

Fig. 1 is a simplified diagram of the structure of the surface foreign matter inspection apparatus pertaining to a first example of the present invention;

Fig. 2 is a diagram illustrating the two band-shaped irradiation regions formed on the surface of the pellicle 1 in Fig. 1;

Fig. 3 consists of graphs of the scatter signal obtained in the first example, with Fig. 3a showing the scatter signal from the first band-shaped irradiation region 2, and Fig. 3b showing the scatter signal from the second band-shaped irradiation region 3;

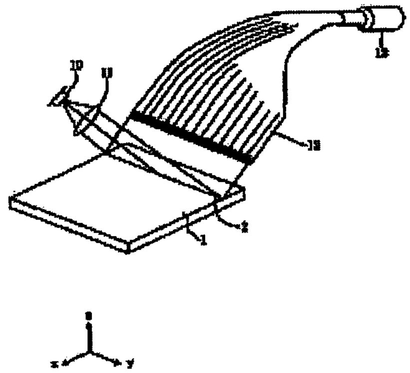
Fig. 4 is a simplified diagram of the structure of the surface foreign matter inspection apparatus pertaining to a second example of the present invention; and

Fig. 5 is a simplified diagram of a variation example of the present invention.

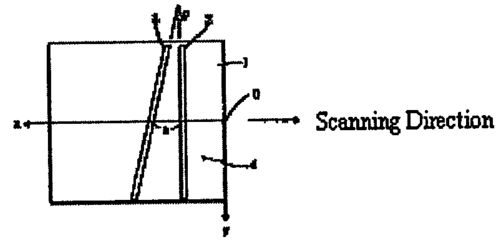
Key:

1 pellicle
2 first band-shaped irradiation region
3 second band-shaped irradiation region
4 foreign matter
10 light source
11 irradiating optical system
12 fiber bundle
13 photoelectric conversion device
14 lens array
15 field stop

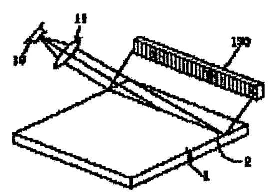
[FIG. 1]



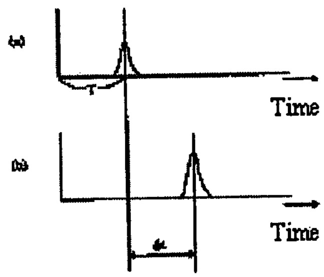
[FIG. 2]



[FIG. 5]



[FIG. 3]



[FIG. 4]